Where minimum reinforcement requirements are not specified in Appendix A, the required cross-sectional area of reinforcement ($A_{s,re}$) to resist concrete splitting forces shall be calculated as follows:

$$A_{s,re} = k_4 \frac{\sum N^*}{\phi_{Ms,re} f_{sy}} \qquad 6.2.6.2(1)$$

where

k_4 = parameter relating to concrete splitting failure that depends on the type of fastener

k_4 shall be taken as one of the following:

(i) 2.0 for deformation-controlled expansion fasteners.

(ii) 1.5 for torque-controlled expansion fasteners.

(iii) 1.0 for undercut and concrete screw fasteners.

(iv) 0.5 for chemical fasteners and anchor channel.

$\sum N^*$ = sum of the design tensile force applied to the fasteners in the fixture in tension

f_{sy} = yield strength of reinforcing steel

$\phi_{Ms,re}$ = capacity reduction factor for tensile failure of supplementary reinforcement

Where neither Item (a) nor (b) applies, the characteristic strength of a fastener or group of fasteners to splitting failure ($N_{Rk,sp}$) shall be calculated as follows:

$$N_{Rk,sp} = N^0_{Rk,sp} \frac{A_{c,N}}{A^0_{c,N}} \psi_{s,N} \psi_{re,N} \psi_{ec,N} \psi_{h,sp} \qquad 6.2.6.2(2)$$

where

$N^0_{Rk,sp}$ = reference characteristic tensile strength of a single fastener to concrete splitting failure, determined in accordance with Appendix A

$A_{c,N}$ = actual projected area of the failure cone of the fastener that is limited by adjacent fasteners and edges of the concrete member (see Clause 6.2.3.3), replacing $c_{cr,N}$ and $s_{cr,N}$ with $c_{cr,sp}$ and $s_{cr,sp}$, respectively that correspond to h_{min}

$A^0_{c,N}$ = reference projected area of the failure cone of a single fastener (refer to Clause 6.2.3.3) replacing $c_{cr,N}$ and $s_{cr,N}$ with $c_{cr,sp}$ and $s_{cr,sp}$ respectively, that correspond to h_{min}

$\psi_{s,N}$ = parameter accounting for the influence on tensile strength of a fastener of the disturbance to the distribution of stresses in the concrete due to the proximity of a fastener to an edge of the concrete member given in Clause 6.2.3.4 with $c_{cr,N}$ being replaced by $c_{cr,sp}$, which corresponds to a member thickness equal to h_{min}

$\psi_{re,N}$ = parameter accounting for the shell spalling effect (refer to Clause 6.2.3.5)

$\psi_{ec,N}$ = parameter accounting for eccentricity of the resultant load in a fastener group, given in Clause 6.2.3.6, with $s_{cr,N}$ being replaced by $s_{cr,Np}$, which corresponds to a member thickness equal to h_{min}

$\psi_{h,sp}$ = parameter accounting for the influence of concrete member thickness on the splitting strength of a fastener under tensile loading

$$= \left(\frac{h}{h_{\min}}\right)^{2/3} \leq \max\left[1, \left(\frac{h_{\text{ef}} + 1.5c_1}{h_{\min}}\right)^{2/3}\right] \leq 2 \qquad 6.2.6.2(3)$$

Where multiple minimum member thicknesses ($h_{\min}$) and corresponding values for effective embedment depths (h_{ef}) are determined for a characteristic edge distance to splitting failure ($c_{\text{cr,sp}}$) in accordance with Appendix A, the value of $h_{\min}$ adopted in Equation 6.2.6.2(2) shall also be adopted in Equation 6.2.6.2(3).

Where the characteristic strength of a single fastener to concrete splitting failure ($N^0_{\text{Rk,sp}}$) is not determined in accordance with Appendix A, it shall be calculated as follows:

$$N^0_{\text{Rk,sp}} = \min\left(N_{\text{Rk,p}}, N^0_{\text{Rk,c}}\right) \qquad 6.2.6.2(4)$$

where

$N_{\text{Rk,p}}$ = characteristic pull-out strength for post-installed mechanical fasteners, determined in accordance with Clause 6.2.4, or replaced by $N^0_{\text{Rk,p}}$, determined in accordance with Clause 6.2.5 for bonded anchors

$N^0_{\text{Rk,c}}$ = reference characteristic tensile strength of a fastener to concrete cone failure, determined in accordance with Clause 6.2.3.2

> ***C6.2.6.2*** *The reinforcement should be placed in a symmetrical manner and close to the fastener(s).*

6.2.7 Concrete blow-out failure

6.2.7.1 General

The strength against concrete blow-out failure shall be considered when $c \leq 0.5h_{\text{ef}}$ for post-installed undercut fasteners. The characteristic strength for concrete blow-out failure shall be considered in each direction independently as follows:

$$N^0_{\text{Rk,cb}} = N^0_{\text{Rk,cb}} \left(\frac{A_{\text{c,Nb}}}{A^0_{\text{c,Nb}}}\right) \psi_{\text{s,Nb}}\, \psi_{\text{g,Nb}}\, \psi_{\text{ec,Nb}} \qquad 6.2.7.1$$

where

$N^0_{\text{Rk,cb}}$ = reference characteristic tensile strength of a fastener to concrete blow-out failure (see Clause 6.2.7.2)

$A_{\text{c,Nb}}$ = actual projected area for the fastener that is limited by the edges of the concrete member ($c_2 \leq 2c_1$), the presence of adjacent fasteners ($s \leq 4c_1$) or the member thickness (see Clause 6.2.7.3)

$A^0_{\text{c,Nb}}$ = reference projected area of a single fastener with an edge distance equal to c_1 [see Figure 6.2.7.3(B) and Clause 6.2.7.3]

$\psi_{\text{s,Nb}}$ = parameter accounting for the disturbance of stresses in the concrete due to the close proximity of the fastener to a corner of the concrete member see (Clause 6.2.7.4)

$\psi_{\text{g,Nb}}$ = parameter accounting for a group effect, refer to Clause 6.2.7.5

$\psi_{ec,Nb}$ = parameter accounting for eccentricity of loading on a fastener group (see Clause 6.2.7.6)

Where a group of fasteners is close to an edge, blow-out failure shall be investigated for the fastener closest to the edge.

6.2.7.2 Characteristic concrete blow-out strength of an individual fastener

The characteristic strength to concrete blow-out failure of an individual fastener remote from the effects of adjacent fasteners and additional edges of the concrete member shall be determined as follows:

$$N^0_{Rk,cb} = k_5\, c_1 \sqrt{A_h} \sqrt{f'_c} \qquad 6.2.7.2$$

where

k_5 = parameter related to the state of the concrete for the determination of the characteristic concrete blow-out strength of an individual fastener

k_5 shall be taken as either of the following:

(a) 8.7 for cracked concrete.

(b) 12.2 for uncracked concrete.

c_1 = edge distance of fastener in direction 1 [see example in Figure 6.2.7.3(A)(a)]

A_h = loadbearing area of the head of the fastener, determined in accordance with Appendix A

f'_c = characteristic compressive strength of concrete at 28 days

6.2.7.3 Geometric effect of edge distance and spacing

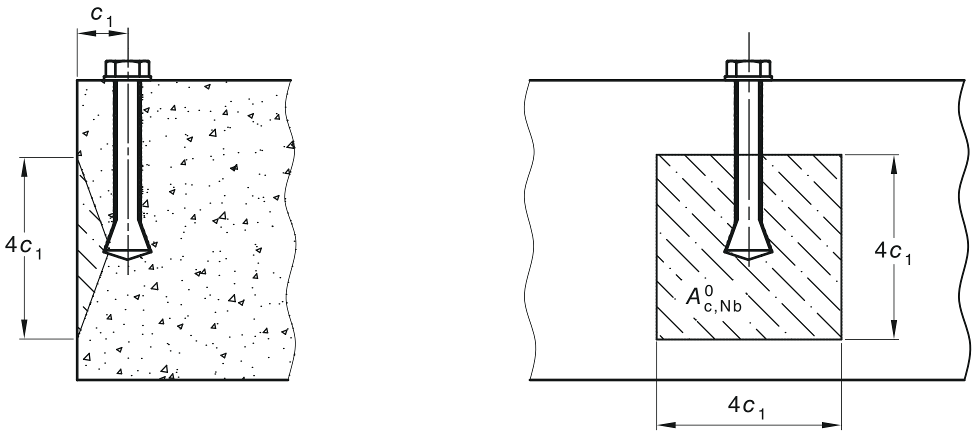
The geometric effect of edge distance and spacing shall be accounted for via the ratio $\dfrac{A_{c,Nb}}{A^0_{c,Nb}}$

where —

$A^0_{c,Nb}$ = reference projected area of a single fastener with an edge distance equal to c_1 [see example in Figure 6.2.7.3(A)(b)]

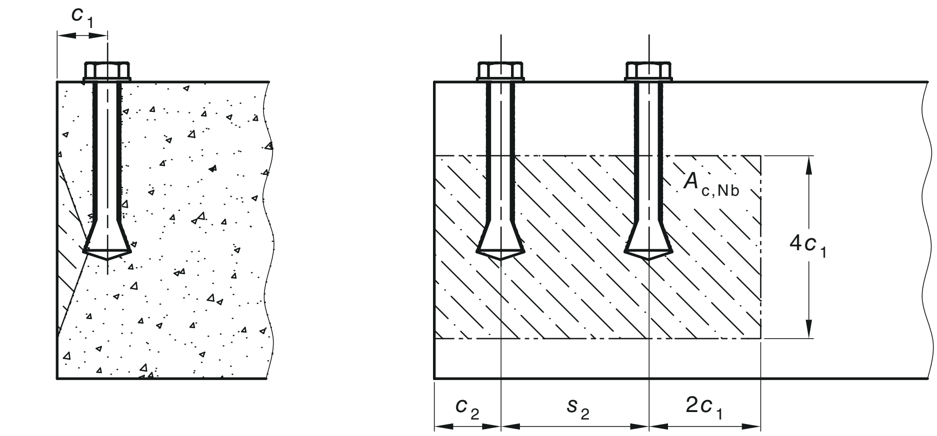
= $(4c_1)^2$

$A_{c,Nb}$ = actual projected area that is limited by the edges of the concrete member ($c_2 \leq 2c_1$) and overlapping areas of adjacent fasteners ($s \leq 4c_1$) or the thickness of the member [see examples in Figures 6.2.7.3(B) and 6.2.7.3(C)]



(a) Break-out body (b) Reference area of break-out body

Figure 6.2.7.3(A) — Examples of idealized break-out body and reference projected area of an individual fastener experiencing concrete blow-out failure



$$A_{c,Nb} = 4c_1(c_2 + s_2 + 2c_1)$$
$$c_2 \leq 2c_1$$
$$s_2 \leq 4c_1$$

(a) Break-out body (b) Idealized area of break-out body

Figure 6.2.7.3(B) — Examples of break-out body and idealized area for multiple fasteners close to an edge experiencing concrete blow-out failure

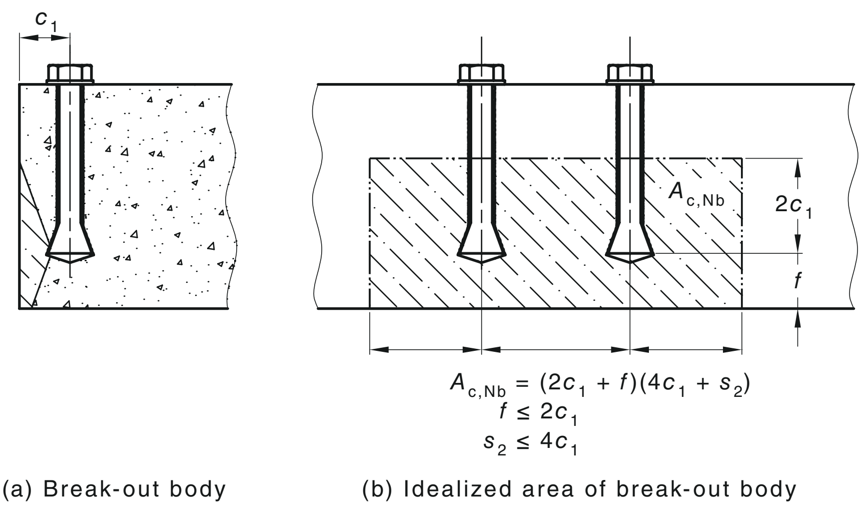


Figure 6.2.7.3(C) — Examples of break-out body and idealized area for multiple fasteners without edge effects

6.2.7.4 Distribution of stresses in concrete

The disturbance to the distribution of stresses in concrete due to the presence of an edge shall be accounted for by the parameter $\psi_{s,Nb}$ as follows:

$$\psi_{s,Nb} = 0.7 + 0.3\frac{c_2}{2c_1} \le 1 \qquad 6.2.7.4$$

where

c_1 = edge distance in direction 1 [see example in Figure 6.2.7.3(A)(a)]

c_2 = edge distance in direction 2, that is the smallest edge distance in a narrow member with multiple edge distances

6.2.7.5 Effect of closely spaced fasteners

The group effect of closely spaced fasteners shall be accounted for by the parameter $\psi_{g,Nb}$ as follows:

$$\psi_{g,Nb} = \sqrt{n} + \left(1 - \sqrt{n}\right)\frac{s_2}{4c_1} \ge 1 \qquad 6.2.7.5$$

where

n = number of fasteners in a row parallel to the edge of the concrete member

s_2 = spacing of fasteners in direction 2

$\le$ $4c_1$

c_1 = edge distance of fastener in direction 1

6.2.7.6 Eccentricity of loading on a fastener group

The parameter $\psi_{ec,Nb}$ accounts for a group effect when there is a difference in tension loads acting on individual fasteners in a group and shall be calculated in accordance with Clause 6.2.3.6 by substituting $\psi_{ec,Nb}$ for $\psi_{ec,N}$ and $s_{cr,Nb}$ for $s_{cr,N}$ where —

$$s_{cr,Nb} = 4c_1 \quad (6.2.7.6)$$

= spacing that is required for a fastener to develop its characteristic tensile strength against concrete blow-out failure

6.2.8 Supplementary reinforcement

Where the fastener design includes provision for supplementary reinforcement, the supplementary reinforcement shall be designed in accordance with AS 3600. The failure modes considered in the design of supplementary reinforcement shall include the following:

(a) Steel fracture of the supplementary reinforcement.

(b) Anchorage failure of the supplementary reinforcement.

6.2.9 Redundant fastenings in non-structural applications

6.2.9.1 Assumptions

In redundant systems for non-structural applications, it is assumed that when failure or excessive slip of one fastener occurs the load is redistributed to adjacent fasteners without impairing the requirements of the fixture for serviceability and ultimate limit state

6.2.9.2 Design

Verification of fasteners in redundant non-structural applications shall be in accordance with Appendix E or Clause 6.2.1 and Appendix H may be used.

6.3 Cast-in anchor channel

6.3.1 General

The verifications in Table 3.4.2.2 shall be undertaken in accordance with Clauses 6.3.2 to 6.3.7.

6.3.2 Steel failure

6.3.2.1 General

The following characteristic strength values, as determined from Appendix A, shall be used:

(a) Channel bolt fracture ($N_{Rk,s}$).

(b) Anchor fracture ($N_{Rk,s,a}$).

(c) Connection between anchor and channel ($N_{Rk,s,c}$).

(d) Basic value for local flexure of channel lips ($N^0_{Rk,s,l}$).

(e) Local flexure of channel lip ($N_{Rk,s,l}$).

(f) Flexure of channel ($M_{Rk,s,flex}$).

6.3.2.2 Characteristic strength against lip failure

The characteristic strength to channel lip failure ($N_{Rk,s,l}$) shall be calculated as follows:

$$N_{Rk,s,l} = N^0_{Rk,s,l}\,\psi_{l,N} \quad 6.3.2.2(1)$$

where

$N^0_{Rk,s,l}$ = basic characteristic strength for local channel lip failure determined in accordance with Appendix A

$$\psi_{l,N} = 0.5\left(1+\frac{s_{cbo}}{s_{l,N}}\right) \leq 1 \quad 6.3.2.2(2)$$

s_{cbo} = actual spacing of channel bolts under tensile loading

$s_{l,N}$ = characteristic spacing of channel bolts under tensile loading for channel lip failure, determined in accordance with Appendix A

6.3.3 Concrete cone failure

6.3.3.1 General

The strength against concrete cone failure shall be determined according to one of the following conditions:

(a) If $h_{ch}/h_{ef} \leq 0.4$ and $b_{ch}/h_{ef} \leq 0.7$, h_{ef} shall be determined from Figure 1.3(B)(a) and the characteristic strength against concrete cone failure shall be calculated according to Equation 6.3.3.1.

(b) If $h_{ch}/h_{ef} > 0.4$ or $b_{ch}/\ h_{ef} > 0.7$ the characteristic strength against concrete cone failure shall be calculated according to Equation 6.3.3.1 using one of the following:

(i) $h_{ef} = h_{ef}{}^*$ where $h_{ef}{}^*$ is determined according to Figure 1.3(B)(b).

(ii) h_{ef} is determined according to Figure 1.3(B)(a); however, the value of $s_{cr,N}$ used in Equation 6.3.2.2(2) shall be determined according to Appendix A and shall be not less than the value of $s_{cr,N}$ used in condition (a) above where $h_{ch}/h_{ef} \leq 0.4$ and $b_{ch}/h_{ef} \leq 0.7$.

The characteristic strength of a single anchor in a channel profile to concrete cone failure shall be calculated as follows:

$$N_{Rk,c} = N^0_{Rk,c}\,\psi_{ch,s,N}\psi_{ch,e,N}\psi_{ch,c,N}\psi_{re,N} \quad 6.3.3.1$$

where

$N_{Rk,c}$ = characteristic strength of a single anchor in anchor channel to concrete cone failure

$N^0_{Rk,c}$ = reference characteristic tensile strength of a fastener, remote from the effects of adjacent anchors or edges of the concrete member, to concrete cone failure, calculated in accordance with Clause 6.2.3.2

A modified effective embedment depth (h'_{ef}) shall be adopted if the fastener is situated in a narrow member (see Clause 6.3.3.5)

$\psi_{ch,s,N}$ = parameter accounting for the influence of neighbouring anchors on the concrete cone strength of a single anchor in an anchor channel profile given in Clause 6.3.3.2

$\psi_{ch,e,N}$ = parameter accounting for the influence of an edge of the concrete member on the concrete cone strength, given in Clause 6.3.3.3

$\psi_{ch,c,N}$ = parameter accounting for the influence of a corner on the concrete cone strength, given in Clause 6.3.3.4

$\psi_{re,N}$ = parameter accounting for the shell spalling effect given in Clause 6.2.3.5

> ***C6.3.3.1*** *The anchor channel may have an adverse effect on the concrete strength; however, this is accounted for in the k_{cr} and k_{ucr} values.*

6.3.3.2 Influence of neighbouring anchors

The factor $\psi_{ch,s,N}$ accounting for the influence of neighbouring anchors on the concrete cone strength shall be calculated as follows:

$$\psi_{ch,s,N} = \frac{1}{1 + \sum_{i=1}^{n_{ch,N}} \left[\left(1 - \frac{s_i}{s_{cr,N}}\right)^{1.5} \frac{N_i}{N_o} \right]} \qquad 6.3.3.2(1)$$

where

$n_{ch,N}$ = number of anchors within a distance equal to $s_{cr,N}$ of the anchor under consideration (for an example, see Figure 6.3.3.2)

s_i = distance between anchor under consideration and neighbouring anchor “i”

$s_{cr,N}$ = characteristic spacing of the anchor to ensure the characteristic tensile strength of a single anchor

$$= 2\left(2.8 - 1.3\frac{h_{ef}}{180}\right)h_{ef} \geq 3h_{ef} \qquad 6.3.3.2(2)$$

N_i = tension force in an influencing anchor “i” within a distance equal to $s_{cr,N}$ of the fastener under consideration

N_o = tension force in the anchor under consideration

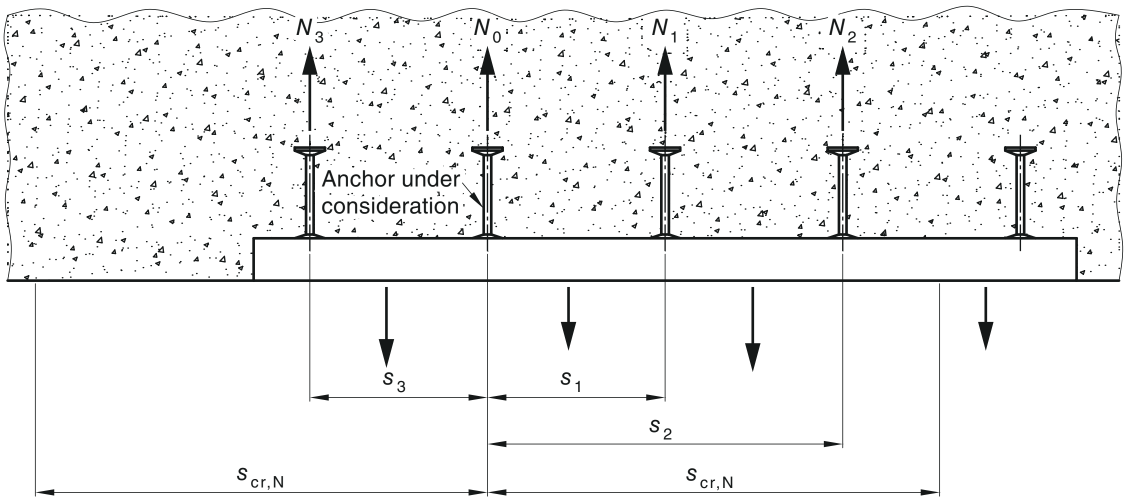


Figure 6.3.3.2 — Example of anchor channel containing multiple point loads

6.3.3.3 Influence of an edge

The factor $\psi_{ch,e,N}$ accounting for the influence of an edge on the concrete cone strength of a single anchor shall be calculated as follows:

$$\psi_{ch,e,N} = \left(\frac{c_1}{c_{cr,N}}\right)^{0.5} \leq 1 \qquad 6.3.3.3$$

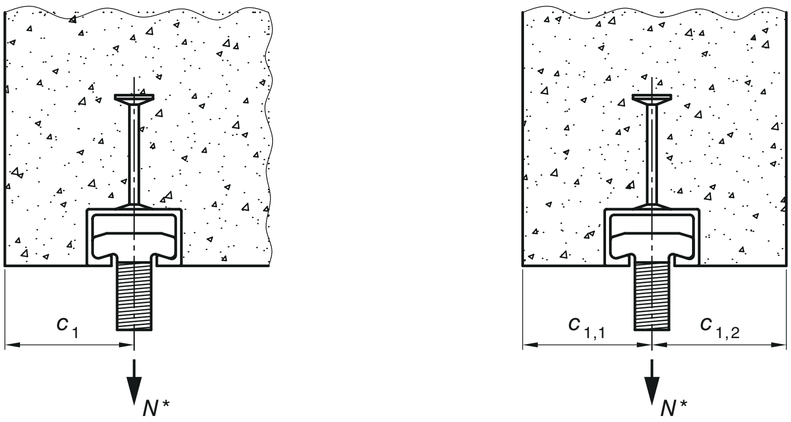
where

c_1 = edge distance of the anchor channel [see Figure 6.3.3.3(a)]

$c_{cr,N}$ = characteristic edge distance of the anchor to ensure the characteristic tensile strength of a single anchor

= $0.5s_{cr,N}$

When the anchor under consideration is situated in a concrete member containing multiple edge distances [e.g. $c_{1,1}$, $c_{1,2}$ in Figure 6.3.3.3(b)] the minimum edge distance shall be adopted in Equation 6.3.3.3.



(a) Close to an edge (b) Narrow member

Figure 6.3.3.3 — Example of anchor channel located close to an edge and within a narrow member

6.3.3.4 Influence of a corner

The parameter accounting for the influence of a corner on the concrete cone strength ($\psi_{ch,c,N}$) shall be calculated according to the following:

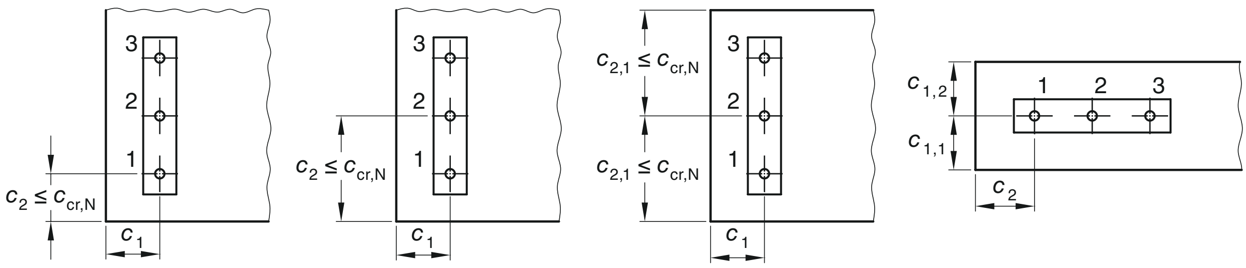
$$\psi_{ch,c,N} = \left(\frac{c_2}{c_{cr,N}}\right)^{0.5} \leq 1 \qquad 6.3.3.4$$

where

c_2 = edge distance in direction 2 for the anchor under consideration, as illustrated in Figure 6.3.3.4

$c_{cr,N}$ = characteristic edge distance of the fastener to ensure the characteristic tensile strength of a single fastener

If the anchor is influenced by two corners [e.g. $c_{2,1}$, $c_{2,2}$ in Figure 6.3.3.4(c)], $\psi_{ch,c,N}$ shall be determined for both distances and the product of the factors $\psi_{ch,c,N}$ shall be inserted in Equation 6.3.3.1.



(a) Anchor ‘1’ under consideration (b) Anchor ‘2’ under consideration (c) Anchor ‘2’ under consideration (d) Anchor ‘1’ under consideration

Figure 6.3.3.4 — Establishing the corner distance of an anchor in anchor channel located close to a free edge